July 29, 2005

Ms. Carol Hammel-Smith
Fuel Economy Division
National Highway Traffic Safety Administration
Room 5320
400 7th Street
Washington, DC 20590

Re: Peer Review of CAFE Compliance and Effects Modeling System (Final)

Dear Ms. Hammel-Smith,

This document represents the final letter report associated with my review of the CAFE Compliance and Effects Modeling System which is being developed by NHTSA with technical support from the Volpe National Transportation System Center.

In accordance with the contracted Statement of Work, the purpose of the review was to highlight potential changes in methods, data and assumptions that could enhance the model. We were further requested to evaluate the extent to which methodological changes could yield better results and likewise, to what extent changes to data and process assumptions might improve the analyses.

I wish to compliment the NHTSA staff on the efforts that have been conducted, to date, in preparing the code and the responsiveness in answering all technical questions posed. However, based upon my review of the technical approach, there are fundamental assumptions behind the National Academy of Science (NAS) report on the Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards that severely limit their applicability to the process being considered under the NHTSA model.

Accordingly, significant and perhaps unacceptable errors will likely result when applying the NAS incremental technology fuel economy improvement estimations to individual manufacturer vehicles.

The NAS estimations were developed as “Class-Averaged Estimates” in which variations across manufacturers and vehicle types were “averaged out” over a large distribution of vehicles. However, the assessment of potential fuel consumption improvements on individual vehicles requires, in my opinion, significant engineering assessment and engine, powertrain and full vehicle modeling that was not conducted by the NAS committee.

In the discussion below, I will attempt to provide some additional background information and further discussion of my concerns and recommendations.

Background

As you are aware, I was a member of the NAS Committee on the Effectiveness of Corporate Average Fuel Economy (CAFE) Standards, whose final report was released by the National Research Council in January 2002. Within our report, we concluded that “technologies exist that, if applied to passenger cars and light trucks, could significantly reduce fuel consumption within15 years.”

The committee was charged with reviewing the effectiveness and impact of existing CAFE standards and providing recommendations for future consideration. During the course of our review, the committee desired a practical method by which potential improvements in fuel economy could be estimated when considering the application of current and advanced technologies to vehicles sold in the U.S. An approximation methodology was developed, as described in the NAS report, which you have accurately documented and utilized in your code.

However, the approach was intended as, and is limited to, a way of providing the Committee with estimates of what might be possible within a class of vehicles. Accordingly, by a class, we considered an entire vehicle class which is represented by a distribution of vehicles across a variety of manufacturers. Stated another way, a hypothetical vehicle was defined with characteristics that were derived from sales-weighted averages of all vehicles sold within a particular vehicle class. This hypothetical vehicle was considered representative of the class and a starting point for estimating potential fuel consumption improvements.

Under this assumption, we believed that general estimations were possible of what might be accomplished when looking at a class as a whole. These assumptions required significant engineering judgment which was provided by qualified members of the committee under the constraints of the committee resources and timetable. However it is my opinion that one cannot simply apply this approach to any individual vehicle and get an accurate prediction of improvements in fuel consumption.

The method necessary to more accurately estimate potential improvements in fuel consumption of individual vehicles requires detailed engine, transmission and vehicle performance maps, transient data, calibration information, transmission shift points, and a whole host of other data that vehicle manufacturers consider proprietary. As discussed in the CAFE Committee proceedings, this would require thousands of engine and vehicle simulations that still rely on assumptions, proprietary data and must be calibrated against experimental data before significant conclusions can be drawn. Although theoretically possible, it is my opinion that such an effort is not feasible and would still require proprietary data which is only known to the individual manufacturers.

It is this concern that causes me to suggest that the approach you have outlined in your code is an inappropriate use of the NAS data. Furthermore, due to the approximate nature of our estimates and the compounding error that occurs as an increasing number of technologies are added, we stated in the CAFE report that our fuel consumption analyses and the break-even cost analyses cannot and should not be used to recommend fuel economy goals. Using the same data in an attempt to estimate the potential approaches an individual manufacturer would use to comply with future standards is equally flawed, in my opinion.

Technical Discussion

As part of our vehicle class analysis, we attempted to identify a theoretical or hypothetical vehicle which was defined by assessing a sales-weighted average for vehicle characteristics and technology features within a class. For example, if the number of engine cylinders was determined to be 7.5 per vehicle sold (a sales-weighted average between 8, 6 and perhaps 5 or 4), then we assumed that the class-representative vehicle had an 8 cylinder engine. If the result was 6.4 cylinders per vehicle, we would then assume a 6-cylinder engine as class representative.

This process was followed for all major engine, transmission and other vehicle characteristics, such as vehicle weight. This approach allowed us to determine a representative vehicle from which to begin the engineering judgmental process of applying technology “paths” that the members of the committee deemed possible for different types of vehicles. For instance, the application of cylinder deactivation to 4-cylinder engines is theoretically possible, but the resulting roughness of the powertrain is potentially unacceptable. It was this type of judgment that was used in our approach. However, the class-representative vehicle is hypothetical and is not representative of any one vehicle in the class.

Another very important technical issue is the potential for compounding error and the possibility of approaching or exceeding theoretical limits for benefits that can be realized as additional technologies are subsequently applied. During the course of the CAFE proceedings, we assessed the potential improvement in fuel consumption in the form of ranges, both in potential improvement and the associated cost increase. Accumulation of these ranges with an increasing number of technologies will become very large, as we identified in the CAFE report. Again, on a class-averaged basis, we accepted averaged values as representative. However, when one evaluates individual vehicles, such ranges would need to be reduced through much more detailed analyses than we conducted, in order to draw meaningful conclusions.

An equally important range-related factor is the associated incremental cost. Early in the public comment period, it became apparent that the use of cost ranges could be skewed toward desired results. Certain parties attempted to argue that significant fuel economy gains were possible with very little cost increase. Likewise, others argued that very little improvement would be achieved at significant cost.

The problem is that they can both be correct, or incorrect, depending upon the individual vehicle boundary conditions, the age of vehicle, where the powertrain systems are in their development, plant depreciation cycles, and so on. Therefore, again we believed that on a class-averaged basis, approximate values for fuel consumption improvement and cost were reasonable. However, they are likely erroneous on an individual vehicle and manufacturer-specific basis.

Also, as additional technological improvements are incrementally considered, it is important to assess the limitations in reducing losses, for instance in reducing friction, pumping (gas exchange) losses, aerodynamics, etc. This can result in so-called "double dipping" which was the subject of quite some debate during the CAFE proceedings. Evaluating hypothetical, class-averaged vehicles reduces, but does not eliminate this potential error. However, on an individual vehicle basis, there is an increased likelihood of compounding error that could exceed practical and even theoretical limits. This is where the detailed engine, powertrain and vehicle simulation analyses, that rely on proprietary data are needed to reduce the likelihood of significant errors.

Response to SOW Questions

Several specific questions were listed in the Statement of Work (SOW) for which comment and answers were requested. Below please find my thoughts associated with each technology-related question.

Q1): *Please comment on the "engineering conditions" that we employed (Table 3 in documentation) to constrain the applicability of various technologies.*

It appears that the NHTSA computer model employs the technology assessment techniques of the NAS report, applies them to individual OEM vehicles within some assumed sales fleet and then predicts the ability to comply with a proposed CAFE scenario. The model weighs the cost of non-compliance fines against the predicted incremental cost of adding additional technology (production-intent or emerging) and balancing these potential scenarios for each vehicle model and manufacturer. The computer model then, apparently, considers the impact that this will potentially have on the marketplace.

As outlined in the Background section of this report, I have critical reservations about applying the technology versus cost parameters taken from the NAS CAFE report to individual vehicle models. The NAS report technique was based on identifying an “average hypothetical vehicle” for each vehicle class to determine engineering judgment-based “likely technology” (production-intent and emerging) that will be available over the next 15 years versus the estimated cost of that technology (in 2002 dollars). In my opinion, this approach cannot be transferred to a “vehicle model-specific” method, as used in this computer code.

Under the boundary conditions of the CAFE Committee, we attempted to identify likely technology scenarios for different classes of vehicles. These so-called “paths” relied on engineering judgment and some general knowledge of technology introductions. In some cases, technology introductions will not follow a cost benefit path, but may be related to the ease of implementation, even at higher unit cost, or perhaps marketing trends. Certainly, one can use the NHTSA code to evaluate “what-if” scenarios, but the accuracy of the predictions is questionable, becoming increasingly so as more technologies are accumulated.

Another technical issue and basis for concern, in my opinion, is the increasing difference between in-use fuel consumption and that which is measured in the EPA city, highway and combined cycles. As new technologies, such as idle-off, mild hybridization and diesel engines enter the fleet, differences between the certification and on-road results will likely increase.

If the primary purpose of the code is to evaluate the influence on compliance when evaluated under the EPA test cycles (keeping in mind the concerns expressed above), then certain conclusions could be drawn. However if the analysis chooses to evaluate actual fuel savings (in gallons) over the ownership or life of the vehicle, plus the influence on resale value, then more attention should be paid to these differences.

Q2). *Please review and comment on our logic (Figure 3, Figure 4) and surrounding text in documentation) we have developed to simulate the application of technologies in response to CAFE standards.*

I have commented extensively on my concern related to the applicability of applying the NAS incremental improvements on an individual vehicle basis. The following comments refer only to the logic shown in Figures 3 and 4.

The compliance simulation and "next-best" selection algorithm (Figures 3 and 4) may not predict the actual preferred or desired path taken by any individual manufacturer on any individual model (or models with the same powertrains) regardless of the CAFE scenario.

Under these logic algorithms, it is possible that the choice of the "next-best" technology could go in an improbable direction for individual manufacturers and/or vehicle models. For example, a particular manufacturer may choose a specific "next best" technology, such as "accessory-load reduction." However, another manufacturer could skip this benefit and proceed with some other technology introduction because they plan a new engine design introduction for non-CAFE compliance reasons, perhaps driven by marketing input or performance enhancement. Another manufacturer may have a completely different set of boundary conditions leading to yet another preferred solution.

Therefore, although the NHTSA code may be used to evaluate possible scenarios, the ability to predict actual market-driven options is highly questionable.

Q3). *Please review and comment on our input assumptions (Table C-5 and similar) regarding the applicability, cost, and effectiveness of different technologies*.

The "Technology Input" files, (table C-5) appear similar to the NAS report tables with the addition of material substitution options, dieselization and the addition of a midrange hybrid. In conversations with NHTSA technical staff, I understand that there are some potential differences in the values from those included in the CAFE Committee report, based upon updated published information and input from manufacturers. There also appear to be three (3) additional columns in the file: "year available", "phase-in" and "kWeight".

"*Year-Available*": The "year available" column is apparently intended to determine the year in which the technology is available for application in production vehicles. It appears that the assumption is that all manufacturers will have the technology available at the same time.

This assumption may not be correct, depending upon the ease of applicability of certain technologies to existing architectures, such as cylinder deactivation. However, we further understand that it is possible to "override" the availability of a technology (in the "Vehicle Models Worksheet", "Engines Input Worksheet" or the "Transmission Worksheet") to compensate for these factors, as a precondition for the chosen scenario.

"*Phase-In*": A further change from the technology assessment made by the CAFE Committee is the "phase-in". This appears to be a correction factor for the likelihood that, once a new technology becomes available, manufacturers will be limited in their ability to integrate the new technology into existing vehicles. Therefore, a percentage "phase-in" is included to show the "uptake" rate of the technology. This is an attractive feature, when combined with the corrected year-available in which technology integration boundary conditions are considered. However, it requires significant knowledge of market conditions and may be difficult to predict

"*kWeight*": The CAFE Committee assumed that, initially, due to additional safety requirements, the vehicle weight would increase by 5%. This was included in the estimates for fuel consumption. Later in the technology matrix, it was assumed that material substitution could occur, thereby removing the 5% weight penalty. Accordingly, only one weight reduction scenario was considered. The NHTSA code has apparently assumed that there could be four (4) different weight changes: three (3) reductions and one (1) increase.

Q4). *Have we thoroughly represented specific technologies? Have we omitted technologies that we should include, or are there others currently included that we should omit? If additional technologies are suggested, what input assumptions should we make regarding applicability, cost, and effectiveness, and what "engineering constraints" should we apply? (pp. C9-C11)*

The addition of "dieselization" and "hybridization" technologies, which were referenced in the CAFE Report but not included in the technology options, is quite appropriate at this time. They represent somewhat expensive options, but with the increasing price of fuel and a growing national recognition of the importance of fuel economy, their expanding use is highly likely.

However, the inclusion of these technologies will further exacerbate the error in the NHTSA assumption that a vehicle's fuel economy is constant with respect to both age and accumulated mileage, and that the test versus on-road fuel economy gap is identical for all vehicle types and ages. There has been significant press given to the issue of EPA test cycle versus real-world experience in hybrid vehicles. However, as more technologies are introduced which address different kinds of efficiency loss in the vehicle, there is increasing likelihood that this mileage gap will continue to widen.

There is also significant evidence that the fuel consumption improvement through the application of advanced diesel technology increases with heavier vehicles.

These factors should likely be considered in any future analyses to help offset the expected production cost trade-offs.

Recommendations

Although I cannot support the use of the CAFE Committee incremental technology improvements on individual vehicles, I believe that the NHTSA code can be used for several important functions.

First, it provides a very valuable and easy-to-use tool to assess potential trends in technology introduction and what the *class-based fleet* would possibly demonstrate in potential improvements and associated costs. As such the code could be used to assist in interactive discussion with different manufacturers during the rule making process and used to solicit input from the OEM's on a vehicle model-specific basis.

Second, I believe that the code can be used to evaluate strategies that individual manufacturers are following as they introduce new technology. Over time, NHTSA could potentially gain a better understanding of the particular technologies that different manufacturers are pursuing and what their relative gains have been, based upon careful tracking and assessment of technology introductions and the associated vehicle characteristics which result. However, I do not believe that the code could be used to predict future compliance scenarios with any reasonable degree of certainty.

Third, the code could be used to calibrate real-world fuel consumption improvements through a careful program of demonstration vehicles and fleet tests. In the end, the ultimate goal is to achieve a reduction in oil consumption and gauge the cost. The code would allow a mechanism to understand how different technologies influence in-use results and make recommendations on procedural directions. However, ultimately, proprietary vehicle manufacturer data may be necessary to fully understand these trends.

I wish to thank NHTSA for giving me the opportunity to review the CAFE Compliance and Effects Modeling System and I look forward to participating in the reviewers panel and file assessment report.

Sincerely,

Gary W. Rogers
President and CEO
FEV Engine Technology, Inc.